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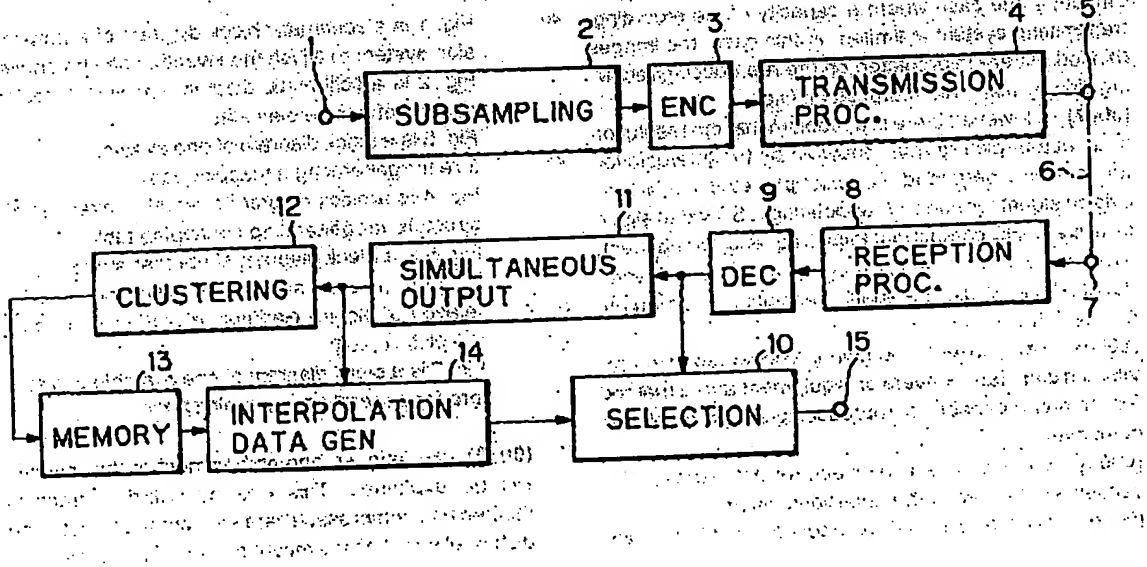
(54) Digital data conversion equipment

(57) Digital data conversion equipment, comprises; means for analysing plural input data and performing clustering depending on a distribution state of the plural input data, means for generating class data associated with output data for each class on the basis of the plural input data and known output data, memory means for storing the class data at an address corresponding to the class, read-out means for reading out class data at an address corresponding to class information subjected to clustering based on the plural input data, and output data generating means for generating output data based on output class data of the read-out means.

Fig. 1



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Description

[0001] This invention relates to a digital data conversion equipment and a method for the same, which are applicable to an interpolation of a thinned picture element in data conversion, up-conversion for converting a television signal with standard resolution into a television signal with high resolution and so on.

[0002] There are generally two kinds of systems for converting a digital video signal. One of them is a system for converting a signal whose resolution is high with respect to the space or time or a signal having a large amount of information into a signal of a low resolution. The other is a system for converting, on the contrary, a signal whose resolution is low with regard to the space or time or a signal having a small amount of information signal of a high resolution.

[0003] In the former case, a signal having inherently a large information amount is converted into a signal of a small information amount. For example, by properly thinning out a picture element information amount or field/frame information, a signal of a low space/time resolution can be easily formed.

[0004] The above example relates to what is called a down converter to, for instance, convert a video signal of a high definition (HD) system into a video signal of a standard definition (SD) system. Various kinds of techniques have already been proposed.

[0005] The latter case, contrarily, relates to an up conversion to, for instance, convert a video signal of the SD system to a video signal of the HD system. An example in which an electronic zooming process is executed or an enlargement of an image is performed is considered. In those examples, hitherto, information which inherently lacks is interpolated by using an interpolation filter and the interpolated information is used.

[0006] As still another example, there is a sub-sampling method for periodically thinning out pixel data in order to compress a recording/transmission data amount in the case where a capacity of the recording/transmitting system is limited. In this case, the images thinned out are interpolated on the reproducing/receiving side by using an interpolation filter.

[0007] However, there is a problem that the resolution of an output picture from obtained by the interpolation with a filter is degraded. For example, even if a HD television signal formed by interpolating a SD video signal by a filter, a HD component (high frequency component) which is not present in an input SD signal is not reproduced. As a result, the spatial resolution of an output picture is lowered.

[0008] The present invention is concerned with providing digital data conversion equipment and a method for the same capable of reproducing a high resolution component.

[0009] Various aspects and features of the present invention are defined in the appended claims.

[0010] According to one embodiment of the present invention, there is provided a digital data conversion equipment, comprising:

means for analysing plural input data and performing clustering depending on a distribution state of the plural input data;

means for generating class data associated with output data for each class on the basis of the plural input data and known output data;

memory means for storing the class data at an address corresponding to the class;

read-out means for reading out class data at an address corresponding to class information subjected to clustering based on the plural input data; and

output data generating means for generating output data based on output class data of the read-out means.

[0011] According to another embodiment of the present invention, there is provided a digital data conversion method, comprising:

training step for analysing plural input data, performing clustering depending on a distribution state of the plural input data, generating class data associated with known output data for every class on the basis of the plural input data and the output data, and storing the class data into a memory depending on the class;

step for clustering the plural input data and reading out class data at an address of the memory corresponding to the class; and

step for generating output data based on the class data.

[0012] The invention will now be more particularly described, by way of illustrative and non-limiting example, with reference to the accompanying drawings, in which:

Fig. 1 is a schematic block diagram of a transmission system to which the invention can be applied;

Fig. 2 is a schematic diagram showing a position relation of picture elements;

Fig. 3 is a block diagram of one example of a structure for generating a mapping table;

Fig. 4 is a block diagram of another example of a structure for generating a mapping table;

Fig. 5 is a block diagram of another embodiment;

Fig. 6 is a schematic diagram showing a position relation of picture elements of a SD picture and a HD picture; and

Fig. 7 is a block diagram of one example of a structure for generating a mapping table.

[0013] Hereunder, one embodiment of this invention will be explained. This one embodiment transmits thinned and compressed data and reproduces a thinned picture element on the reception side. Fig. 1 shows such

a transmission system as a whole. In Fig. 1, reference numeral 1 is an input terminal for digital video data to be transmitted.

[0014] Input digital video data is supplied to a sampling circuit 2, and picture element data positioned alternately is thinned out in the horizontal direction. As shown in Fig. 2, picture elements indicated at X in the array of the original picture elements show the thinned picture elements a result, with this thinning-out process, the data amount necessary for transmission is reduced to half.

[0015] The output data of the sampling circuit 2 is supplied an encoder for highly efficient coding. For the highly efficient coding, orthogonal conversion coding such as DCT (Discrete Cosine Transform), ADRC (Dynamic Range Adaptive-type Coding) and so on, which are well known, can be adopted. With this encoder 3, the data amount to be transmitted is reduced.

[0016] The output data of the encoder 3 is fed to a transmission processing circuit 4. The transmission processing circuit 4 performs processing such as error correction coding, frame formation and channel coding. Transmission data is generated and an output terminal 5 of the transmission processing circuit 4. The transmission data is through a transmission line 6. The transmission line 6 is limited to a communication line and includes processes of magnetic recording and reproduction in its meaning.

[0017] Reception data is fed through an input terminal 7 to a reception processing circuit 8. The reception processing circuit 8 performs processing such as decoding of channel coding, frame decomposition, and error correction. The output of the reception processing circuit 8 is given to a decoder 9 for highly efficient coding. The decoded output of the decoder 9 is supplied to a selecting circuit 10 and a simultaneous output circuit 11.

[0018] The simultaneous output circuit 11, as shown in Fig. 2, produces transmission picture element data a, b, c, and d, which are present at upper and lower positions and left and right positions with respect to a thinned picture element x to be interpolated, to a clustering circuit 12 and an interpolation data generating circuit 14, simultaneously. Output data from the clustering circuit 12, i.e., class information is given to a memory 13 as an address signal.

[0019] A mapping table for data conversion formed in a manner mentioned later is etored in the memory 13. In this example, a mapping table including plural parameters is stored in the memory 13. A parameter read out from an address corresponding to the output data of the clustering circuit 12 is supplied to the interpolation data generating circuit. The interpolation data generating circuit 14 provides interpolation data x by the calculation of:

$$x = w1\,a + w2\,b + w3\,c + w4\,d$$

using transmission picture element data a, b, c, and d from the simultaneous output circuit 11 and parameters w1, w2, w3, and w4 from the memory 13.

[0020] The interpolated data x is supplied to the selecting circuit 10. The selecting circuit 10 selects the output the decoder 9 when a transmission picture element is present, while the selecting circuit 10 selects interpolated data from the interpolation data generating circuit 14 at a position of a thinned picture element. Consequently, decoded video data corresponding to reception data is provided at an output terminal 15 of the selecting circuit 10.

[0021] A mapping table formed in advance by training is stored in the memory 13. Fig. 3 shows a structure for forming the mapping table. In Fig. 3, a digital video signal is supplied to 21 and to a simultaneous output circuit 22. It is desirable that the digital video signal is a standard signal taking into a count the generation of a mapping table. For example, for the video signal, a signal composed of a still picture with various patterns can be adopted. As shown in Fig. 2, the simultaneous output circuit 22 supplies a data memory 23 and a clustering circuit 24 simultaneously with data a x, which is a target picture element, and picture element data a, b, c, and d, which are present in upper and lower positions and left and right portions with respect to the data x. It is to be noted that actual value exists without any thinning of the target picture element at the time of the training shown in Fig. 3.

[0022] The clustering circuit 24 carries out the clustering picture element data to generate class information as the clustering circuit 12 of Fig. 1 does. For clustering, clustering by gradation, clustering by a pattern, etc., can be used. In the use of the gradation, the number of classes becomes extremely large if picture element data has eight bits. As a result, it is desirable that the bit number of each picture element is reduced with highly efficiency coding such as ADRC. For pattern use, plural patterns composed of four picture elements (for example, evenness, increase of a value in the right and upper direction, decrease of a value in the right and lower direction, etc.) are prepared, and the output data of the simultaneous output circuit 22 is classified into any one of the plural patterns.

[0023] The output of the clustering circuit 24 is given to one input terminal 25a of a switching circuit 25. The output of a counter 26 is supplied to the other input terminal 25b of the switching circuit 25. The counter 26 generates addresses, which sequentially change, by counting clock CK. The output of the switching circuit 25 is supplied to the data memory 23 and a memory 28 for parameters as their addresses.

[0024] Sample values of picture element a, b, c, d, and x are written into the data memory 23 with respect to addresses which are class information. For example, $(a_{10}, a_{20}, \ldots, a_{no})$ with respect to the picture element data a, $(b_{10}, b_{20}, \ldots, b_{no})$ as to the picture element data b, $Cc_{10}, c_{20}, \ldots, c_{no}$ with respect to the picture element data c, and $Cd_{10}, d_{20}, \ldots, d_{no}$) as to the picture element data

d are stored in a certain address AD0 of the data memory 23. As for other addresses from the clustering circuit 24, picture element data is stored in the memory 23 similarly.

[0025] Next, the switching circuit 25 is switched from the input terminal 25a to 25b, and the content of the data memory 23 is sequentially read out by an address from the counter 26. The read-out of the data memory 23 is supplied to an arithmetic circuit 27 of the least square method. With this minimum square method, parameters w1 to w4 are obtained with minimum error.

[0026] When attention is paid to one address, the following simultaneous equations are established with respect to this address.

$$x1 = w1a1 + w2b1 + w3c1 + w4d1$$

$$x2 = w1a2 + w2b2 + w3c2 + w4d2$$

$$xn = w1an + w2bn + w3cn + w4dn$$

[0027] Now, since x1 to xn, a1 to an, b1 to bn, c1 to cn, and dl to dn are known in advance, the parameters w1 to w4 are obtained so that the square of the error for x1 to xn (actual values) is minimised. This applies to other addresses.

[0028] The parameters w1 to w4 obtained at the arithmetic circuit 27 are written into a memory 28. A mapping table which has been written into the memory 28 is stored in the memory 13 of Fig. 1. Therefore, the value of x, which is a thinned picture element, is produced at the interpolation data generating circuit 14 using the parameters produced from the memory 13.

[0029] For the mapping table, not only the above-stated parameters but also the one from which output data values themselves are provided may be employed. In this case, the interpolation data generating circuit 14 in Fig. 1 can be omitted. Fig. 4 shows a structure for forming the mapping table. Similarly to the structure of Fig. 3, plural picture element data made simultaneously is supplied to the clustering circuit whose output is supplied to a data memory 30 and a frequency memory 31 as an address.

[0030] The read-out output of the frequency memory 31 is give to an adder 32 and added by +1. The output of the adder 32 is written into the same address of the memory 31. For the memories 30 and 31, each content of their addresses is cleared at zero as the initial stage.

[0031] Data read from the data memory 30 is supplied to a multiplier 33 and multiplied by a frequency which is read out of the frequency memory 31. The output of the multiplier 33 is given to an adder 34 and added to the input data x there. The output of the adder 34 is supplied to a divider 35 as a dividend. To the divider 35, the output of the adder 32 is fed as a divisor. The output of the divider 35 (quotient) becomes input data of the data memory 30.

[0032] In the above-mentioned structure of Fig. 4, data x1 is directly written into the memory 30 and the value of a corresponding address of the memory 31 is brought to 1, since the read outputs of the memories 30 and 31 are zero. If this address is accessed once again later, the output of the adder 32 is 2, and the output of the adder 34 is (x1 + x2). As a result, the output of the divider 35 is (x1 + x2)/3, which is written into the memory 30. On the other hand, the frequency 2 is written into the frequency memory 31. Further, when the above-mentioned address is accessed, the data of the memory 30 is updated to (x1 + x2 + x3)/3. The frequency is also updated to 3.

[0033] By carrying out the above-mentioned operation within a determined period, a mapping table is stored into the memory 30 so that data, which is present at that time, is output when a class is designated by the output of the clustering circuit. In other words, when plural picture element data of an input video signal is given, a mapping table can be formed so that data is output to correspond to its clustered data on the average.

[0034] Another embodiment of the invention shown in Fig. 5 is for up conversion of a SD video signal to a HD video signal. In Fig. 5, a digital SD video signal is supplied to a terminal indicated at 41. Examples of the SD video signal are a reproduction signal, a broadcast signal, etc., of SDVTR. The SD video signal is given to a simultaneous output circuit 42 whose output data is supplied to clustering circuit 43. The output of the clustering circuit 43 is sent as an address signal to memories 44a to 44d where mapping tables M1 to M4 are stored.

[0035] Fig. 6 partially shows a relationship between a SD picture and a ND picture. In Fig. 6, picture element data by circles 0 belongs to the SD picture, while picture element data indicated by crosses X belongs to the ND picture. For example, four picture element data y1 to y4 of the HD picture is generated from twelve picture element data of the SD picture. The mapping table M1 of the memory 44a is for generating picture element data y1, while the mapping tables M2, M3, and M4 are for generating picture element data y2, y3, and y4, respectively.

[0036] The read-out outputs of the memories 44a to 44d are given to a selector 45. The selector 45 is controlled by the output of a selection signal generating circuit 46. A sampling clock of the ND picture is supplied from an input terminal 47 to the selection signal generating circuit 46. The four picture element data y1 to y4 is selected sequentially by the selector 45 and is supplied to a scanning conversion circuit 48. The scanning conversion circuit 48 generates picture element data of the ND picture in the order of raster scanning at an output terminal 49. A monitor for ND is connected to the output terminal 49 through a D/A converter (not shown). The number of picture elements of an output picture is four times that of picture elements of an input SD video

signal.

[0037] Fig. 7 shows one example of a structure for generating the mapping tables M1 to M4 stored in the memories 44a to 44d. In Fig. 7, a digital ND video signal is supplied to an input terminal indicated at 51. It is desirable that the ND video signal is a standard like signal taking into account the generation of the mapping tables. Actually, by taking a standard picture with a ND video camera or by recording a taken picture signal onto HDVTR, a HD video signal can be provided.

[0038] The ND video signal is supplied to a simultaneous output circuit 52. The simultaneous output circuit 52 simultaneously produces picture element data a to 1 andy1 to y4 having a relationship in positions shown in Fig. 6. The picture element data a to 1 is supplied to a clustering circuit 53. The clustering circuit 53 performs the classification of gradation patterns, etc., as in the above mentioned one embodiment. The output of the clustering circuit 53 is commonly given to mapping table generating circuits 54a to 54d.

[0039] The picture element data y1 to y4 is supplied to the mapping table generating circuits 54a to 54d have the same construction. The one similar to the structure for obtaining average value as shown in Fig. 4 can be adopted for the mapping table generating circuits 54a to 54d. In the case of the mapping table generating circuit 54a,y1 a is supplied in place of the picture element data x in Fig.4. For the mapping table generating circuit 54a, the same structure of Fig. 4 can be employed. In addition, with the use of parameters, the same structure as Fig. 3 may be used for mapping generating circuits 54a to 54d.

[0040] Mapping tables showing the correlation between the HD video signal and the SD video signal are stored in the mapping table generating circuits 54a to 54d. In other words, when plural data of the SD video signal is given, a mapping table, which outputs picture element data of the ND video signal on the average corresponding to the one provided by clustering these a plural data, can be formed. This mapping table is stored in the memories 44a to 44d with the structure of Fig. 5.

[0041] Although the above-mentioned one embodiment is an example where the up-conversion of the SD video signal to the ND video signal is made, the invention can be applied similarly to the enlargement of a picture, besides this embodiment.

[0042] With the above arrangement, data transmitted with a thinning-out system can be received, and a thinned picture element can be interpolated without the deterioration of resolution. When picture element data lacking at the time of picture element enlargement is interpolated, the invention is applicable in a similar manner. Also, the above arrangement not only permits a video signal with standard resolution to be converted to that with high resolution but also allows a picture with high resolution to be displayed on a monitor.

[0043] Having described specific preferred embodiments of the present invention with reference to the accompanying drawings, it is to be understood that the invention is not limited to those precise embodiments, and that various changes and modifications may be effected therein by one skilled in the art.

Claims

1. A learning apparatus for learning parameters (w1, w2, w3, w4) used for converting a first image signal into a second image signal by forming all pixels of the second image signal in accordance with pixels of the first image signal, the learning apparatus comprising:

   outputting means (22) for outputting first learning image signals corresponding to the first image signal and second learning image signals corresponding to the second image signal,

   determining means (24) for determining a class for a pixel(x) of the second learning image signals by picture content of a group of pixels (a-d) of the first learning image signals adjacent to the pixel(x) of the second learning image signals, producing means (27) for producing the parameters (w1, w2, w3, w4) for each of a plurality of classes based upon the groups of pixels (a1-d1, ..an-dn) of the first learning image signals and the pixels (x1-xn) of the second learning image signals, and

   memory means (28) for storing the parameters (w1, w2, w3, w4) for each of a plurality of classes.

2. A learning apparatus according to claim 1, wherein said producing means (27) produces the parameters (w1, w2, w3, w4) for each of a plurality of classes by solving equations for minimising the square of the errors for the pixels (x1-xn) of the second learning image signals for each of a plurality of classes.

3. A learning apparatus according to claim 1, wherein said determining means (24) determines a class for a pixel (x) of the second learning image signals based on a pattern of the group of pixels (a-d) of the first learning image signals.

4. A learning apparatus according to claim 1, wherein said determining means (24) determines a class for a pixel (x) of the second learning image signals based on a gradation of the group of pixels (a-d) of the first learning image signals.

5. A method for learning parameters (w1, w2, w3, w4) used for converting a first image signal into a second image signal by forming all pixels of the second image signal in accordance with pixels of the first

image signal, the learning method comprising the steps of:

outputting (22) first learning image signals corresponding to the first image signal and second learning image signals corresponding to the second image signal,

determining (24) a class for a pixel (x) of the second learning image signals by picture content of a group of pixels (a-d) of the first learning image signals adjacent to the pixel (x) of the second learning image signals,

producing (27) the parameters (w1, w2, w3, w4) for each of a plurality of classes based upon the groups of pixels (a1-d1,..., an-dn) of the first learning image signals and the pixels (x1-xn) of the second learning image signals, and

storing (28) the parameters (w1, w2, w3, w4) for each of a plurality of classes.

6. Apparatus for converting a first image signal of first resolution into a second image signal of second resolution higher than the first by forming pixels of the second image signal from pixels of the first image signal, the apparatus comprising:

means for determining a classification by picture content of a group of pixels of the first image adjacent to, and from which, a pixel of the second image is to be considered, characterised by

means for producing the considered pixel for pixels of the second image signal in accordance with predicted value for the considered pixel contained in a memory, the memory containing for each of a plurality of classifications, predicted values for the considered pixel generated from a reference image signal having the second resolution, the memory being addressed in accordance with the classification determined by the determining means.

7. Apparatus according to claim 6, wherein the producing means comprises a plurality of memories, each memory containing predicted values of the considered pixels for each of a plurality of classification, the memory being addressed in accordance with the classification determined by the determining means, the memories producing respective predicted pixels, and means for supplying the considered pixels to an output in a predetermined sequence.

8. Apparatus according to claim 6 or 7, wherein the first image signal is of standard definition and the second image signal is of high definition.

9. Apparatus according to any of claims 6, 7 or 8, wherein the first image signal is a signal which some pixels are interpolated from the second image signal.

10. Apparatus according to any of claims 6 to 9, wherein the determining means detects the pattern of the said group of pixels of the first image signal and determines the classification of the pixel of the second image in accordance with the detected pattern.

11. A method of convening a first image signal of first resolution into a second image signal of second resolution higher than the first by forming pixels of the second image signal from pixels of the first image signal, the method comprising the steps of:

determining a classification by picture content of a group of pixels of the first image adjacent to, and from which, a pixel of the second image is to be considered, and

characterised by the steps of

first producing predicted value for the considered pixel generated from a reference image signal having said second resolution from a memory, the memory containing for each of a plurality of classifications, the memory being addressed in accordance with the classification determined by the determining step, and

second producing the considered pixels for pixels of the second image signal in accordance with the predicted values of the considered pixel contained in the memory.

12. A method according to claim 11, wherein plurality of memories are provided, each memory containing predicted values of the considered pixels for each of a plurality of classifications, the memory being addressed in accordance with the classification determined by the determining step, the memories producing respective predicted pixels, and further comprising the step of supplying the considered pixels to an output in a predetermined sequence.

13. A method according to claim 11 or 12, wherein the first image signal is of standard definition and the second image signal is of high definition.

14. Apparatus according to claim 11, 12 or 13, wherein the first image signal is a signal which some pixels are interpolated from the second image signal.

15. A method according to claim 11, 12 or 13, wherein the determining step detect the pattern of the said group of pixels of the first image signal and determines the classification of the pixel of the second image in accordance with the detected pattern.

16. Apparatus or method according to any of claims 11 to 16, wherein the predicted values are produced by training apparatus comprising:

means for determining the classification by picture content of a group of pixels of a reference image, the group being adjacent to a target pixel of the reference image, the target pixel corresponding to a pixel to be considered, the group corresponding to pixels of an image having first resolution, the group together with the target pixels corresponding to pixels of an image having second resolution higher than the first, and

means for deriving for each classification predicted value for the considered pixel from at least the values of the target pixel.

17. Apparatus or method according to claim 16, wherein the deriving means comprises a means for counting the number of occurrence of each classification and means responsive to the counted number for calculating the average value of the target pixel for each classification as the predicted value for the considered pixels.

18. Apparatus or method according to any one of claims 6 to 15, wherein the predicted values are produced by a training method comprising the steps of

determining the classification by picture content of a group of pixels of a reference image, the group being adjacent to a target pixel of the reference image, the target pixel corresponding to a pixel to be considered, the group corresponding to pixels of an image having first resolution, the group together with the target pixels corresponding to pixels of an image having second resolution higher than the first, and

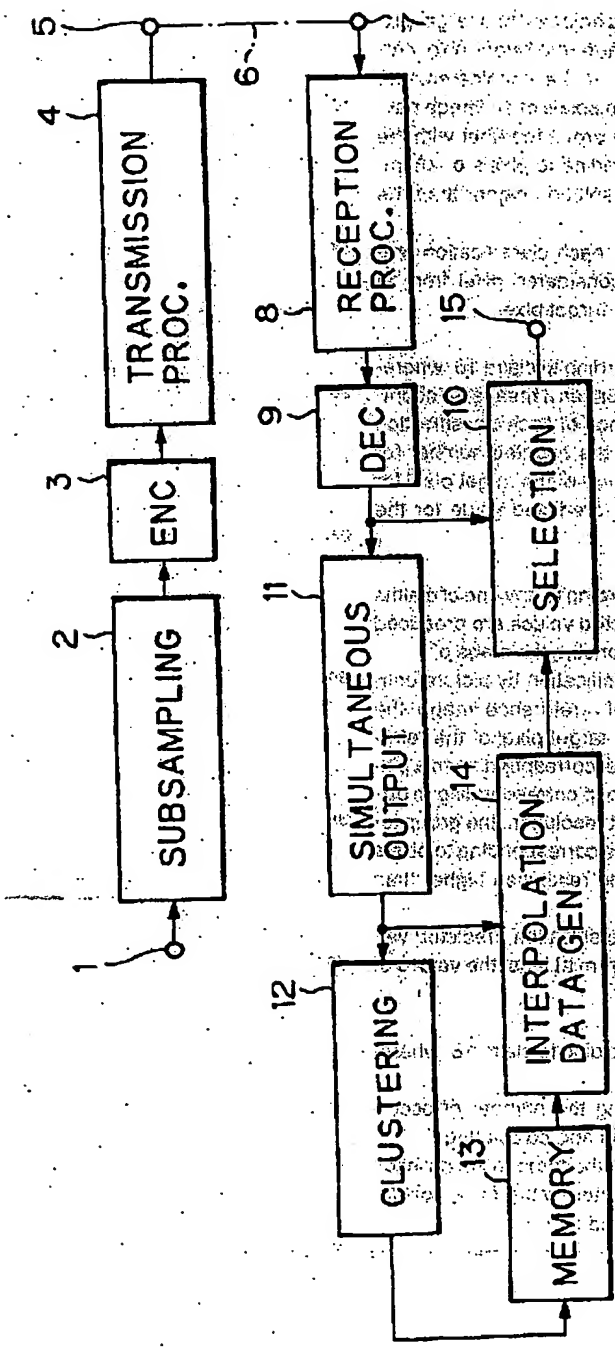
deriving for each classification predicted value for a considered pixel from at least the values of the target pixel.

19. Apparatus or method according to claim 18, wherein the deriving step

comprises a counting the number of occurrence of each classification and calculating

the average value of the target pixel for each classification as the predicted value for a considered pixel using the counted number.

Fig. 1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CLUSTERING
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MEMORY
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INTERPOLATION DATAGEN
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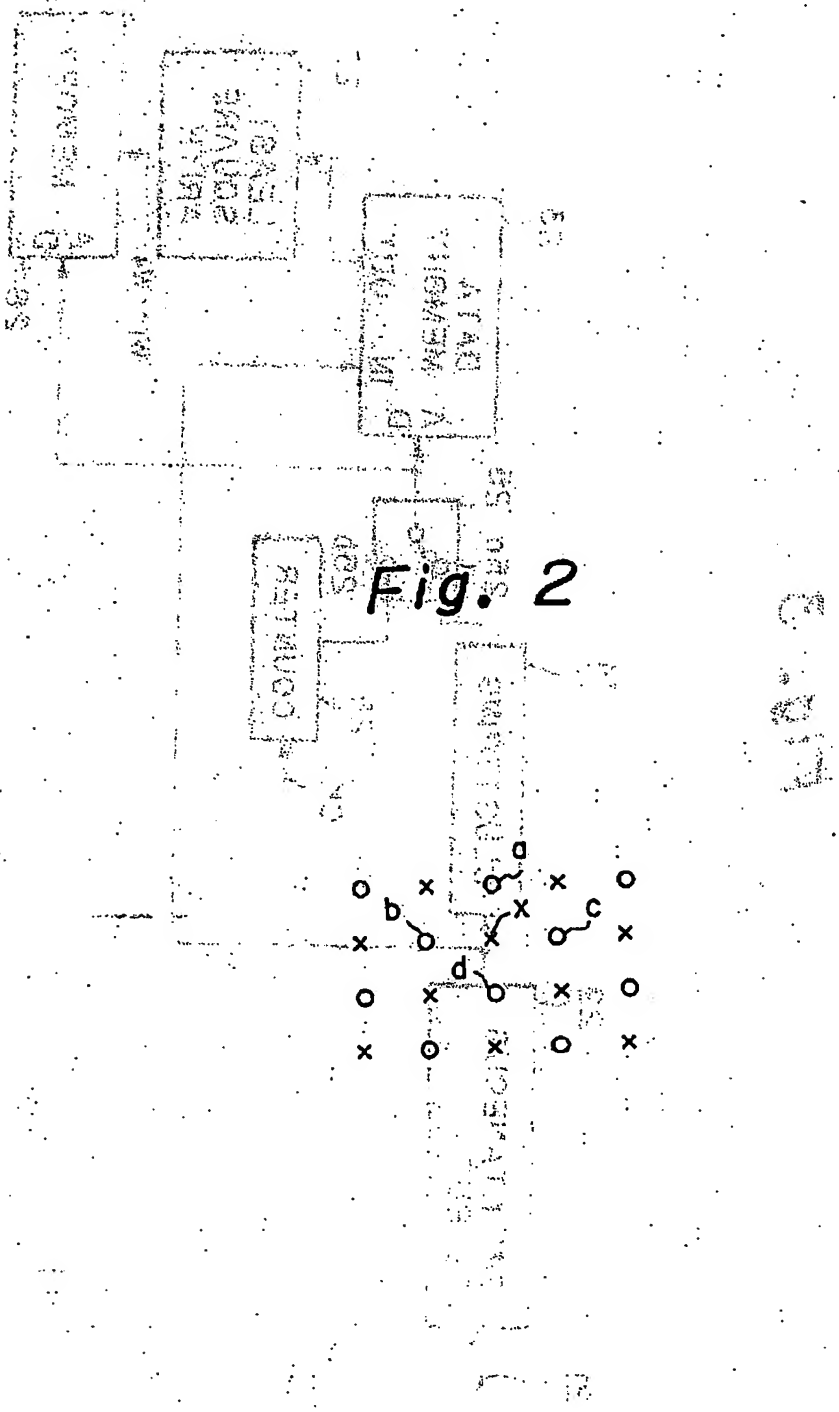

Fig. 2

Fig. 3

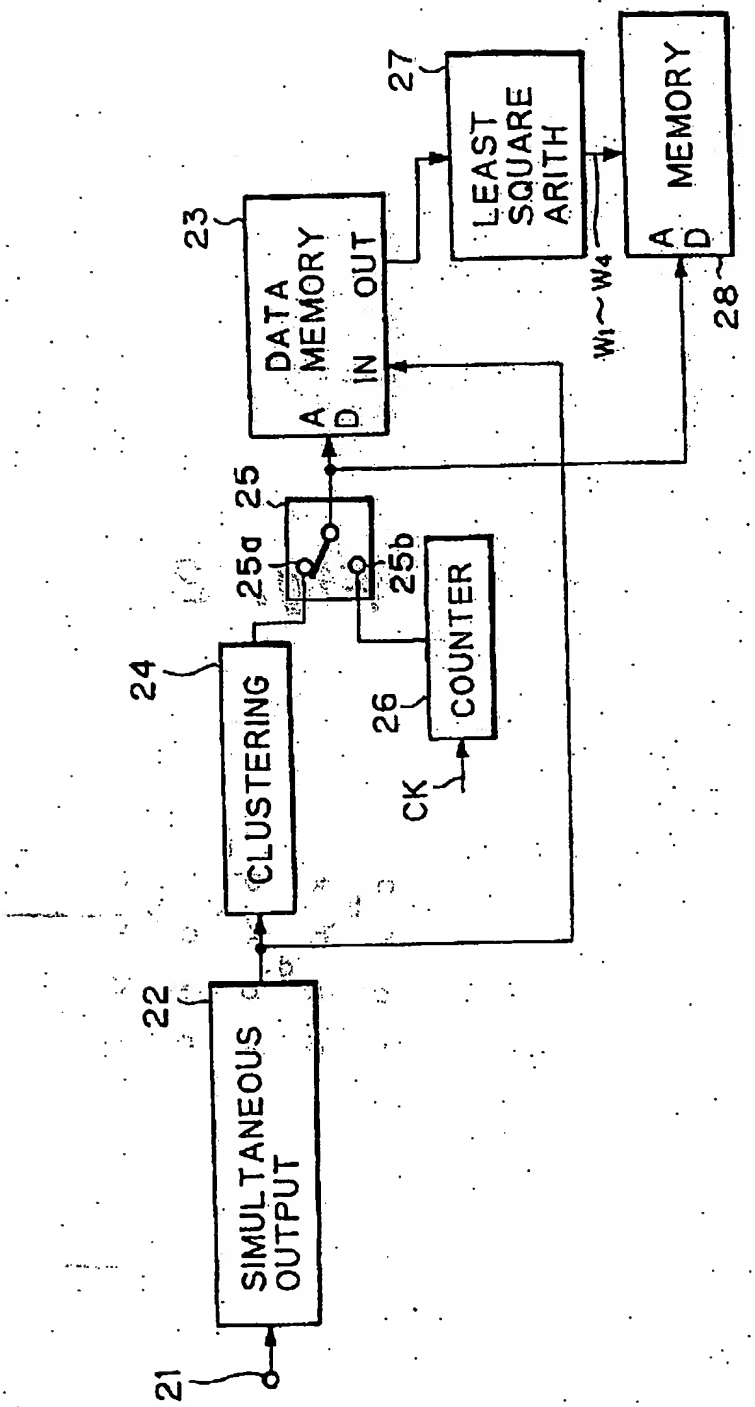
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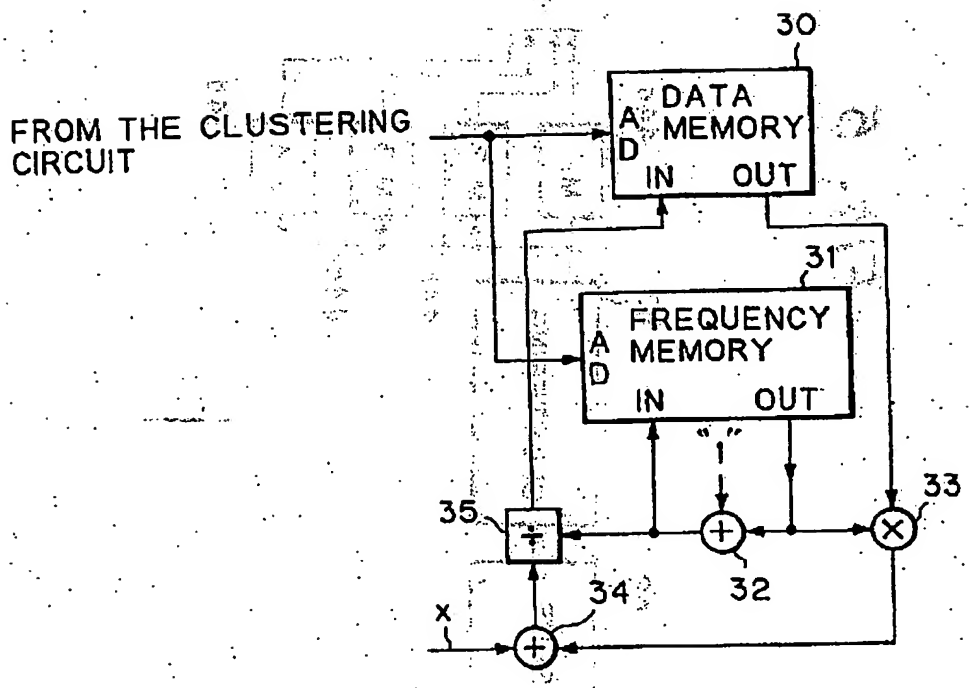
Fig. 4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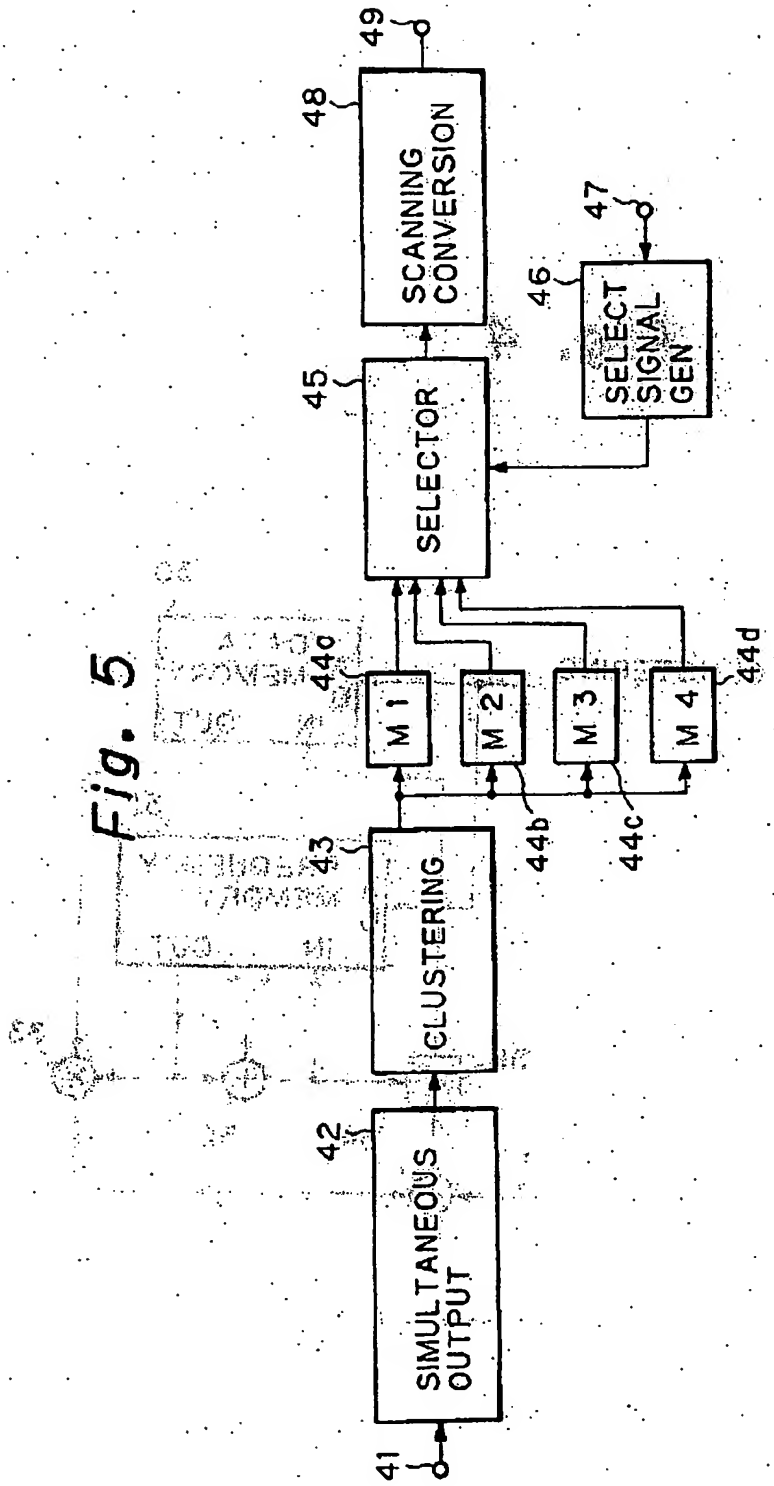
41
SIMULTANEOUS OUTPUT
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CLUSTERING
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M 1
M 2
M 3
M 4
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44b
44c
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SELECTOR
45
SELECT SIGNAL GEN
46
47
SCANNING CONVERSION
48
49

Fig. 5

Fig. 6

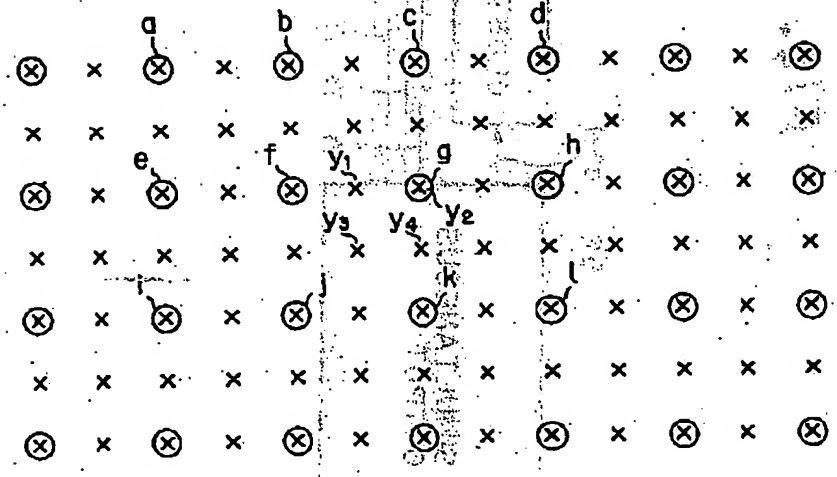
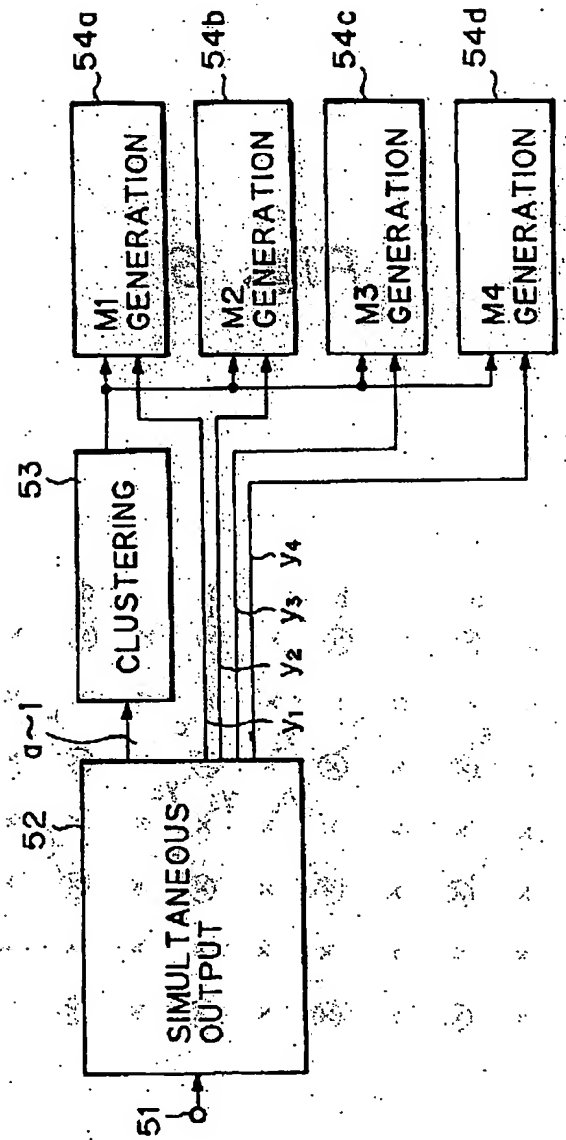


Fig. 7


54a
54b
54c
54d
M1 GENERATION
M2 GENERATION
M3 GENERATION
M4 GENERATION
53
CLUSTERING
q~1
52
SIMULTANEOUS OUTPUT
51
y1
y2
y3
y4

European Patent Office

EUROPEAN SEARCH REPORT

Application Number
EP 03 07 6182

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.7)
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The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	3 June 2003	Beaudoin, O

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